ESL-IC-11-10-23

The ''Sustainable Building - Accelerator''

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ABSTRACT

A method and a tool have been developed to assist the designers from the beginning of the design phase. The costs and benefits for different design options are calculated using Life Cycle Costing (LCC) and are presented in an insightful way to the stakeholders. Traditionally these calculations are only made by cost specialists at the end of the design phase, only quantifying a few design options in detail, instead of using these calculations in the early design stages to generate optimal design solutions.

The ''Sustainable Building - Accelerator" supports stakeholders to decide on sustainable solutions by giving them cost and benefit information of design solutions. This information provides them with valuable input to create their sound business cases.

This article describes the concept and illustrates the added value of the "Sustainable Building - Accelerator".

INTRODUCTION

The "Sustainable Building - Accelerator" evolved from the vision that was presented on January 13th, 2010 at the Technical Council TVVL symposium (Maassen, 2010). Now the first version of the ''Sustainable Building - Accelerator'' has been developed. This first version can be used to compare the performances of different building designs over a longer period of time. The performances include Lifecycle costs.

Many people in the Netherlands and worldwide call out, that it is necessary to accelerate innovations in the built environment, to achieve the high ambitions on sustainability in time.

The ideas for the ''Sustainable Building - Accelerator'' originated from the assumptions that the required acceleration of innovations within the built environment is not yet achieved due to:

- the small amount of innovative solutions which are generated by design teams, because (i) the design process is characterized by mono-disciplinary sequential steps and (ii) the design is most of the time constructed from partial existing solutions;
- the application of innovative design solutions is not considered adequately (not often, not all the pros and cons are considered) and not considered over the lifetime of the building, see Figure 1. This is because: (i) the pros and cons over the lifetime of the building are not within a contract of one single party, or are not clearly linked to parties, (ii) there is no clear method prescribed and (iii) there is no adequate tool available.

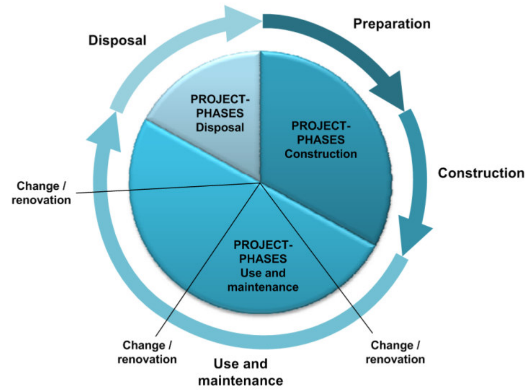


Figure 1. Representation of the life cycle costs compared to the cost of construction and the different costs of which the life cycle costs consist

THE ''SUSTAINABLE BUILDING - ACCELERATOR''

To innovate and accelerate, in addition to develop innovative products and systems, also a new way of working and designing is necessary. This will lead to a demand driven innovations which will accelerate the realization of a sustainable built environment. The "Sustainable Building - Accelerator'' supports a new way of working, designing and making design decisions.

Innovations and the application of sustainable solutions in buildings are stimulated and realized with the "Sustainable Building - Accelerator'' by using a structured and systematic approach during the design phase of the building. Therefore a design methodology and a tool are developed, to support the

Proceedings of the Eleventh International Conference Enhanced Building Operations, New York City, October 18-20, 2011

design team during the early stages of the design with:

- the generation of innovative sustainable building design solutions;
- the selection of innovative sustainable building design solutions (including adjustments and changes over time) considering a longer period.

<u>Generation Of Innovative Building Design Solutions</u>

The research focus of the part "generation of concepts" of the "Sustainable Building - Accelerator" was formulated with reference to previous research in this area (Savanovic, 2009). The argument here is that designers in the early stages of the design of an ambitious and innovative project need methodological support. Hereby it is assumed that the designers are experienced and can work on a highly knowledge-intensive level.

Important aspects in the required design methodology are:

- the organization of the design team (roles and tasks);
- the design process (workshops, etc. to enhance the solution space and find a solution by diverging and converging);
- the method used to design;
- the applied design tools;
- the communication, within the design team, in different design stages of the design process.

<u>Selection Of Sustainable Building Design Solutions – LCC Part Of The ''Sustainable Building – Accelerator'</u>

Design decisions are increasingly made by developers and a growing number of consortia, with an integrated contract (eg DBFMO: Design, Built, Finance, Maintain and Operate), based on a Life Cycle Cost and Life Cycle Performance considerations. The total costs, performances and variations in the use of housing (including building services), are taken into account over a longer period. This is to achieve optimum solutions, where:

- the value of the building for the user and his environment (the environment) is as large as possible;
- a financial benefit is achieved in a market where energy prices rapidly rise, the prices of innovative (e.g. energy saving) products quickly reduce and the flow of new innovative products accelerates;
- in the design innovative solutions are applied and in for the future the application of innovative solutions (adaptation) and changes in the use of the building (flexibility) is taken into account.

This is different from the traditional way of making design and housing decisions. Traditionally, these decisions are taken by a static approach that includes only the initial investment and simple pay out times (SPOT). Using this traditional approach large profit will be missed, see (Nelissen, 2010), and there is no anticipation to dynamic aspects: (a) the targets within integrated contracts to maximize resale value and minimizing operating costs, (b) the rapid changes in the market and (c) the possibilities for adaptation of new techniques.

The LCC part of the ''Sustainable Building – Accelerator'' provides a clear, useful and reliable method and tool, which can be used to make design and housing decisions based on a lifecycle approach, see Figure 2. The ''Sustainable Building – Accelerator'' is broadly applicable and can be used for new and existing buildings from the start until the end of the design stage.

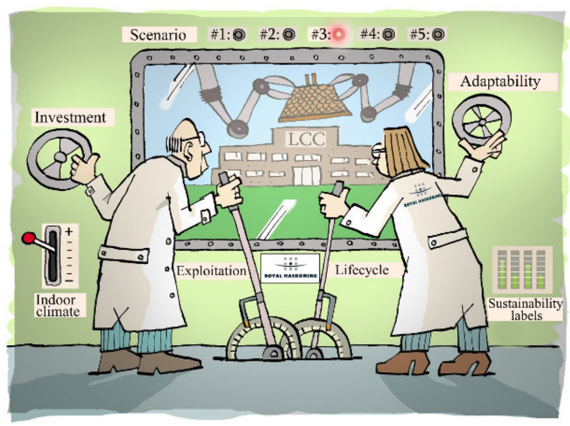


Figure 2. Schematic representation of part of the ''Sustainable Building – Accelerator'': method and tool to make design decisions considering the lifetime of the building

THE "SUSTAINABLE BUILDING - ACCELERATOR'': LCC PART

The LCC method and tool, as part of the ''Sustainable Building – Accelerator'', is developed and presented in this article. The requirements for the development of this method and tool version were:

- Broadly applicable dynamic financial accounting tool where changes over the lifespan (including replacement and improvement investments, energy costs, other operating costs) are clearly specified for four design variants.
- Strong presentation / communication tool that gives insight and a good overview using

indicators (per m^2) and a graphically display of the results of the design variants, see Figure 2,

- Insight in the sensitivity of the results for variations in the different input parameters.
- Applicable to carry out a LCC-study fulfilling the requirements of BREEAM-NL (BRE Environmental Assessment Method for the Netherlands) credit MAN 12 (Dutch Green Building Council, 2010).
- Making clear the benefits: such as savings in labor costs by reducing absenteeism and/or higher productivity due to a better indoor climate. The LCC approach is thus extended to a LCP (Life Cycle Performance) approach.

Near future developments:

- The development of knowledge and the gathering of information to determine the indicators/input to be entered for each relevant design decision to be made.

The available version of the LCC is now a strong communicative and versatile financial calculator. Changes over time can be discounted. The required input depends on the specific design question and should be determined before the "Sustainable Building - Accelerator’’ can be used.

EXAMPLE 1 - ENERGY STUDY

To illustrate how the LCC method and tool works, it is applied to an energy study. This study, for the project Cromstrijen TNO Defence laboratory, has been conducted by Royal Haskoning in the past (Maassen, 2009). The energy study was performed using a traditional static approach and LCC was not applied. To illustrate the added value of the "Sustainable Building - Accelerator’’ it was applied to four different energy generation systems:

- HR+CKM: Boilers and Compression Cooling Machine;
- WKO+HP: Long Term Energy Storage (LTES = WKO) in the Soil (acquifer) and Heat Pump;
- WKK: Cogeneration of Heat and Electricity using Gas (CHP-gas) and Absorption Cooling;
- WKK (bio): Cogeneration of Heat and Electricity using Deep-frying Oil (CHP-bio) and Absorption Cooling.

Examined were:

- how the outcomes / design decisions change using the LCC assessment;
- how sensitive the outcomes of the LCC assessment are for variations in different parameters.

The results of the energy study performed in the past are presented in Table 1.

Table 1. Results of the energy study using a traditional static approach.

Parameters / variation		HR+CKM	WKO+HP	WKK	WKK (bio)
CAPEX	[€/m²]	37,7	60,0	81,6	89,0
energy	[€/(m²*yr)]	14,7	10,5	6,2	4,0
Fraction elect.	[%]	13%	24%	4%	7%
Fraction gas	[%]	87%	76%	96%	0%
Fraction other	[%]	0%	0%	0%	93%
OPEX	[€/(m²*yr)]	1,79	1,61	4,65	5,04
end value	[€/m²]	-20	-30	-40	-40
CO_2	[kg/(m²*yr)]	53	38	11	7
SPOT	[yr]	-	5,1	7,8	6,9

Legend to Table 1:

- CAPEX (Capital Expenditure): Investments. In the statical approach these are onmly the initial investments. In the dynamic approach the CAPEX also includes replacement and improvement investments.
- Energy: Energy costs are taken into account seperately and are divided in the categories gas electricity and other.
- OPEX (Operational Expenditure): Operational costs (here excluding the energy costs), e.g. maintenance, operational management and cleaning costs.
- End value: This is the value of the project at the end of the considered period.
- SPOT (Simple Pay Out Time): This is the resulting simple pay out time using the static approach. Only the initial investment costs and the estimated cost savings on Energy and OPEX after one year are considered.

For the LCC calculation additional data is required to calculate the real, discounted and non-discounted cash flows, see Table 2. These cash flows should also be calculated to fulfill the requirements of BREEAM-NL credit MAN 12, see (Dutch Green Building Council, 2010). The LCC calculation is performed according to the available standards, see (ISO 15686-5, 2008). The capital of the investor is also taken into account in the calculation separately, see "equity" in Table 2.

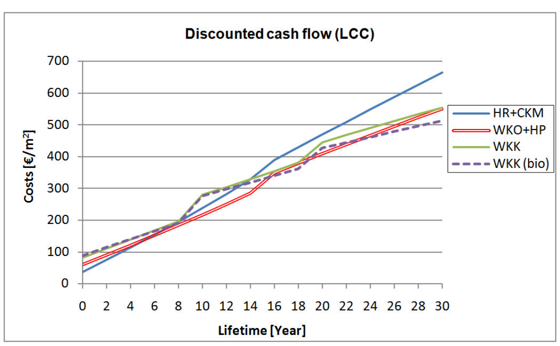
Table 2. Input parameters for LCC calculation (discounted cash flows).

General parameters			
period	n	30	[yr]
electricity price increase	j_e	7%	[%]
gas price increase	j_g	7%	[%]
increase bio oil	j_o	9%	[%]
inflation	j	2,5%	[%]
equity		20	[€/m²]
internal discount rate	R_e	7%	[%]
external discount rate	R_d	6%	[%]
repayment period	n'	30	[yr]
financing interest		6%	[%]

Additionally, scenarios are specified for each variant. Scenarios are specified over a period (here: 30 years in compliance with BREEAM-NL MAN 12). A scenario consists of investments (replacement & improvements, see CAPEX), energy demand (see Energy) and other operating costs excluding energy (see OPEX) over time. In the calculation the following aspects are included:

- replacement investments are included in the scenarios for each variant;
- supply of energy varies over the specified period. The specified values are based on experience. The values indicate that after construction, the energy performance will be lower than expected and each year further it will deteriorate. After renovation, the energy performance will be better than after construction and each year further it will deteriorate again.
- operating costs excluding energy are assumed to be constant over time.

The results of the calculations are presented in Figure 4.



	HR+CKM	WKO+HP	WKK	WKK (bio)
LCC; costing	100%	83%	83%	77%

Figure 4a. LCC results – (accumulated) discounted cash flows for each scenario.

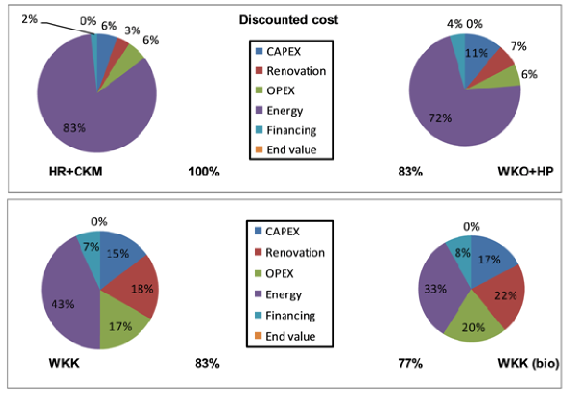


Figure 4b. Breakdown of LCC costs after 30 years for each scenario.

In comparison to the energy study (static approach) the results of the LCC calculation (dynamic approach) show that:

- The payback period (intersection of line with the accumulated costs (cash flow) of the corresponding variant with the reference) differ from the static approach;
- The order of most profitable variants is changed. Application of BIO-Cogeneration of Heat and Power (BIO-CHP) is more profitable than Long Term Energy Storage (LTES = WKO) in the soil in combination with a Heat Pump (HP).
- Furthermore, the results of the LCC calculation show that:
- The breakdown of costs is different for each variant;
- The energy costs are by far the largest costs. Investing in energy saving measures will therefore be profitable;
- Other operating costs excluding the energy costs are low for the reference system and thermal energy storage system (LTES=WKO), but are relatively high for the cogeneration systems (CHP).

The LCC-tool can also automatically determine the sensitivities of the calculated results for variations in input parameters. The sensitivity of the results for the reference system is determined for the variation of different parameters, with values each within a given bandwidth. The considered parameters and their bandwidths are presented in Table 4.

Table 4, Parameters including bandwidths used to determine the sensitivity of the LCC calculation results.

Estimating variables	Base estimate X_m	Range X_a, X_b	Cost outcome based on range C_a, C_b
Internal discount rate	7%	6% to 8%	703 to 609
External discount rate	6%	5% to 7%	686 to 623
Inflation	2,5%	-0,5% to 6,7%	637 to 689
Electricity price increase	7%	6% to 9%	650 to 661
Gas price increase	7%	6% to 9%	631 to 702
Increase price (other)	9%	6% to 12%	653 to 653
CAPEX	38	30 to 45	612 to 685
Energy	15	12 to 18	551 to 778
OPEX	1,79	1 to 2	631 to 638

The calculated sensitivity and coefficient of variance for the reference system are shown in Figure 5.

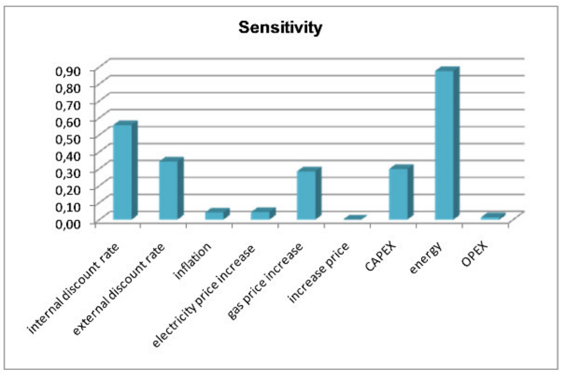


Figure 5a. Calculated sensitivity for the reference system (HR+CKM).

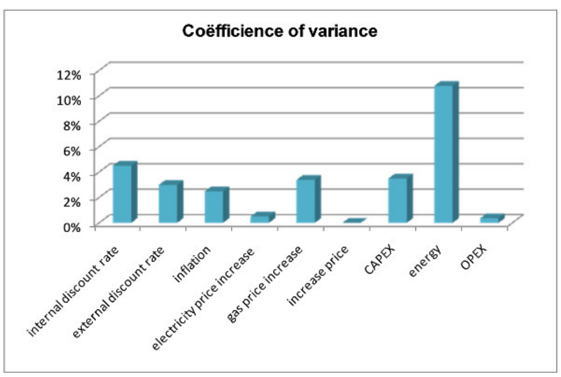


Figure 5b. Calculated coefficient of variance for the reference system (HR+CKM).

The results of sensitivity calculation show that the LCC results are most sensitive to the energy price increase and the discount rate (internal, external).
Since the costs and the breakdown in costs differ for each variant, also the sensitivity for each parameter is different for each variant. Also the scenario's can differ for each variant, e.g. replacements and/or changes are realized in a different years. In order to manage and control future cash flows these sensitivities can already be considered within the design stage of the building.

EXAMPLE 2 – WORKPLACE AIRCONDITIONING

To illustrate how the ''Sustainable Building Accelerator'' works is was used to calculate the Life Cycle Costs and benefits of workplace airconditioning concepts. Four concepts were considered, see Figure 6:

A. induction units in the ceiling (reference/base concept);
B. thermally active building structures (TABS);
C. climate ceiling;
D. individual climate concept.

Life Cycle Costing

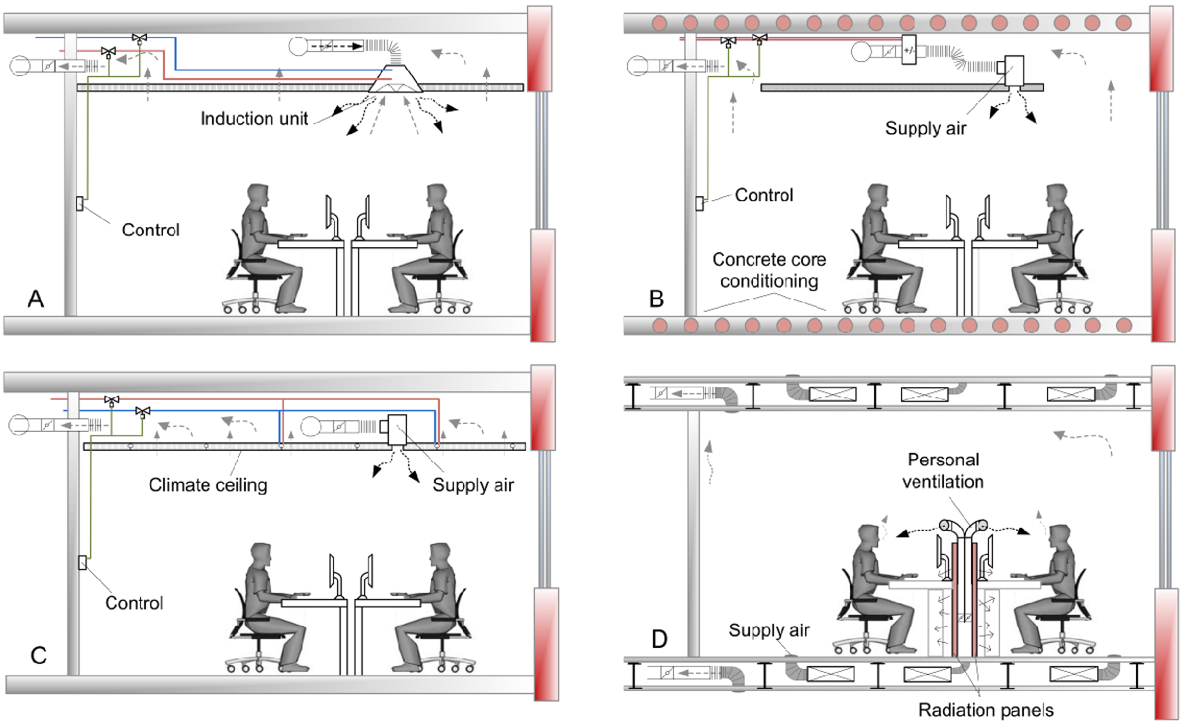
For all concepts the same level of thermal comfort and air quality is realized. The investment costs (CAPEX) are determined considering an office building of 10,000 m^2. For the different concepts the investments cost above 850 €/m^2 are determined. The building services other than the workplace concepts are considered equal. Also Energy, OPEX and replacement costs are considered, see Table 5.

Table 5. Input LCC calculations

Costs		Concept A	Concept B	Concept C	Concept D
CAPEX - investment building services	[€/m^2]	172	201	247	300
CAPEX - construction costs > 850 €/m^2	[€/m^2]	30	140	5	170
Replacement costs after 16 yrs	[€/m^2]	79,6	101,3	160,6	123,7
OPEX - maintenance	[€/m^2 yr]	0,30	0,03	0,25	0,35
Energy costs - gas	[€/m^2 yr]	0,94	0,85	0,89	0,7
Energy costs - electricity	[€/m^2 yr]	5,50	5,08	4,98	2,91
SPOT	[yr]	-	178	81	97

The individual workplace air conditioning system (D) uses a significant less ventilation (Zeiler, 2010). This results in large reduction of energy consumption and energy costs. However concept D requires a relatively high investment.

Within the dynamic calculations also fluctuating energy consumption and different maintenance costs are considered over a period of time. It is assumed that the project is financed by a third party using the same discount for each concept. In Figure 7 circular histograms with the different LCC values for system A and D are presented.



Figuur 6. Schematic presentation of workplace air conditioning concepts. The amount of fresh air and the temperature can be adjusted individually using concept D.

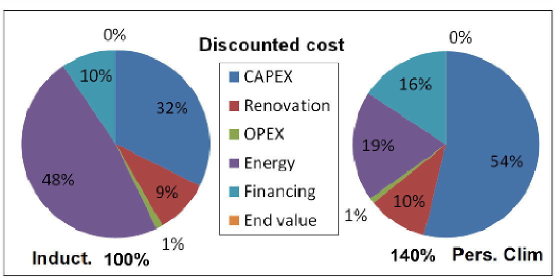


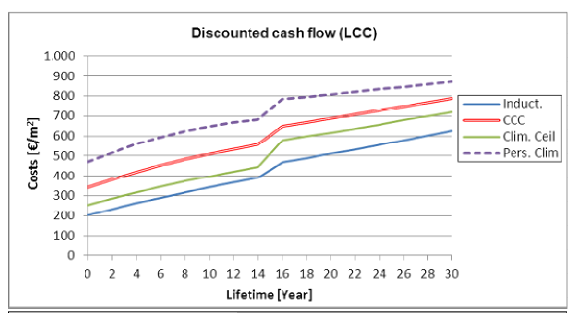
Figure 7. Circular histograms of concept A and D with LCC results.

The breakdown in costs is different for each concept. It can be seen in Figure 7 that the energy costs are the highest cost using concept A (Induct) and the investment costs (CAPEX) are the highest costs using concept D (Pers. Clim).

<u>Productivity</u>

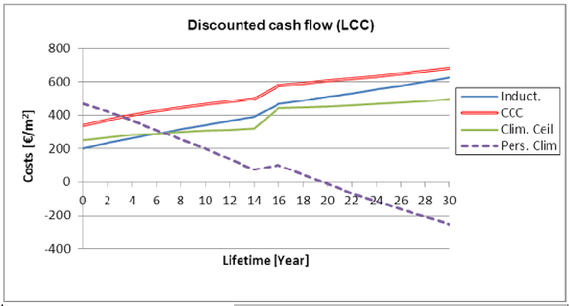
From research and literature (REHVA, 2006) it is known that a better indoor climate results in a higher performance of the building users. Within office buildings the productivity can be improved up to 3%. Considering that 94% of the total costs over the life time are labor costs, a productivity increase of 3% represents a large benefit (ASHREA, 2008; REHVA, 2006). Typical labor costs are € 2.000,- per m^2/year. Considering for each concept the air velocity, temperature radiation, individual temperature control and thermal comfort in between seasons the increase of productivity for each concept compared to the reference concept is: B: 0,25%, C: 0,50% en D: 2,50%.

The LCC results without and with the effect of productivity are presented in Figure 8 and Figure 9.



	Induct.	CCC	Clim. Ceil	Pers. Clim
LCC; costing	100%	126%	115%	140%

Figure 8. LCC results of workplace air conditioning concepts <u>without</u> the effect on productivity.



	Induct.	CCC	Clim. Ceil	Pers. Clim
LCC: costing	100%	108%	79%	-40%

Figure 9. LCC results of workplace air conditioning concepts with the effect on productivity.

The LCC costs in Figure 8 and 9 are discounted cumulative costs over the considered period of 30 years. Although the energy coists for concept D are low the LCC costs are high compared to the other concepts. When the effect of productivity is considered it can be seen in Figure 9 that the effect on LCC costs is high. The concept C has lower LCC costs than concept A (Pay Out Time 7 years) and concept D has even a negative LCC meaning that the income due to the increase of productivity is larger than all LCC costs for workplace air conditioning.

CONCLUSION

The "Sustainable Building - Accelerator'' is a method and a tool that supports the design team making design decisions in the design stage (begin to end) by using a dynamic instead of a traditional static approach. The dynamic approach consists of a LCC calculation based on discounted cash flows and the use of scenario's. The static approach uses only a calculation of the simple pay out time for different variants and no changes and/or modifications over the life time are considered.

The "Sustainable Building - Accelerator'' supports design teams and therefore accelerates sustainable innovations in the built environment using a demand driven approach. The LCC component compares the performance of different scenario's. This enables the consideration of adjustments to enhance the performance of the building in the future.

The developed version of the LCC part of the "Sustainable Building - Accelerator'' allows energy studies, which are not based on a LCC approach, to be extended with a LCC calculation and to extend the variants with scenario's (considering changes and modifications over a longer period or the lifetime). Roadmapping, planning modifications in the future to achieve a better performance, is supported. The LCC method can be used to perform the calculations required by BREEAM-NL credit MAN 12. In general the developed LCC tool is widely applicable and has a strong and insightful presentation of the input and the results. This is shown in the 2 examples in this article.

It was shown that the effect of productivity increase on the LCC results for different workplace air conditioning concepts is very large. Therefore it is advised, when selecting a workplace air conditioning concept, to consider the effect on the indoor climate and the productivity. The effect of productivity increase on the LCC is high and there is already a lot of data available to estimate a productivity increase.

The quality of the data is important to get reliable LCC results. It is advised to perform sensitivity analyses considering the most critical parameters, e.g. increasing energy prices and productivity. When the initial investment costs are too high to choose the concept with the best LCC performance it should be considered to take necessary measures that the concept can be applied at a later time.

FUTURE DEVELOPMENT

In 2010 Royal Haskoning formulated a research and development proposal in collaboration with Eindhoven University of Technology, SBR and the Dutch Green Building Council to develop the "Sustainable Building - Accelerator''. To perform research and development for the full scope of the proposal funding is still required.

Nevertheless Royal Haskoning has already started the development of the "Sustainable Building - Accelerator'' as their own product and service. The priority in the near future is now providing insight into: (a) variations in flexibility (functional changes, shrinkage, expansion) and (b) adaptability (new techniques) for each variant/scenario.

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